TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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WIND-TUNNEL TESTS OF SEVERAL FORMS OF FIXED WING SLOT IN COMBINATION WITH A SLOTTED FLAP ON AN N.A.C.A. 23012 AIRFOIL

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SUMMARY

Several forms of fixed wing slot in a large-chord N.A.C.A. 23012 airfoil were tested in the closed-throat 7- by 10-foot wind tunnel. The airfoil extended completely across the test section so that two-dimensional flow was approximated. The model was fitted with a full-span slotted flap having a chord 25.66 percent of the airfoil chord. The slots extended over the entire wing span. The wing-slot location was varied along the chord and several variations of slot gap and width were tested at each location.

The data are presented in the form of tables of important aerodynamic characteristics for each slot tested and as curves of section lift, profile-drag, and pitching-moment coefficients. The relative air velocity through the slot is given.

A slot as far back on the airfoil as the 55-percent-chord point, with the flap deflected 40°, was practically ineffective for increasing either the maximum lift coefficient or the angle of attack for maximum lift. A slot near the leading edge of the airfoil, with the flap deflected 0°, increased the maximum lift coefficient by 0.65, the maximum angle of attack by 11°, and the minimum profile-drag coefficient by 0.012. With the flap deflected 40°, this nose slot increased the maximum lift coefficient by 0.40 and the maximum angle of attack by 10°.

INTRODUCTION

If the stalling of the wing tips of highly tapered wings can be delayed to a higher angle of attack than that of the center section, the lateral stability and the useful maximum lift coefficient of the wing will be greatly improved. Various methods have been used to make the tips of the wing stall after the center section. Some of these methods are: changing the airfoil section along the span, washout at the wing tips, and either fixed or movable wing slots. If a change in the airfoil section along the span and washout are to be effective in delaying the tip stall with highly tapered wings, they will probably give poor aerodynamic characteristics in the high-speed and the climbing ranges. Leading-edge slots over the tip portion of the wing appear to give the most practical solution of the problem because they have little effect on the span lift distribution for the high-speed and the climbing ranges. Movable slots give a large increase in the angle of attack for the stall and an increase in the maximum lift coefficient. Fixed slots give about the same increases in the maximum angle of attack and the maximum lift coefficient as the movable slots, but they considerably increase the minimum drag coefficient (references 1 and 2). The fixed slots, however, are simpler to construct and are less likely to give operational troubles than the movable slots.

The purpose of this investigation was to determine the effect of some fixed-slot parameters on the aerodynamic characteristics of an N.A.C.A. 23012 wing with a slotted flap. One of the slotted-flap arrangements reported in reference 3 was used because that arrangement appears to be one of the most promising high-lift devices developed up to the present time. The slots were varied in position along the chord, in gap, and in width. The data given in references 1 and 2 for a Clark Y section were used in choosing the slot forms and the slot locations.

APPARATUS AND TESTS

The airfoil was built to the N.A.C.A. 23012 profile with wooden flap and flap-slot forms. The intermediate section of ribs was covered with tempered waterproofed wallboard, and the slot forms were made of wood and metal.

The model has a 3-foot chord and a 7-foot span. The chord of the full-span flap is $0.2566c_w$. The airfoil profile, the dimensions of the flap and the flap slot, and the locations of the flap nose when the flap is deflected are given in figure 1. Figures 2, 3, 4, and 5 show the fixed-slot arrangements with their locations and dimensions. The full-span slots were designed to give systematic variations in gap and width for slat chords of $0.55c_w$, $0.205c_w$, and $0.129c_w$ for one slot. The other slots were obtained by combinations of slat and slot forms.

The model completely spanned the closed test section of the wind tunnel so that two-dimensional flow was practically attained. (See reference 3.)

The velocity of the air flow through the slot was measured by two 1/16-inch-diameter impact tubes located in the smallest part of the slot, one on each side and about one-fourth of the gap from the sides of the slot; the static reference pressure was obtained with a 1/16-inch static tube in the middle of the slot and on a line with the impact openings. For part of the tests, tufts were placed on the upper surface of the airfoil to show the nature of the air flow.

A dynamic pressure of 16.37 pounds per square foot was maintained for all tests, corresponding to an air speed of about 80 miles per hour and to an average test Reynolds Number of 2,190,000. Measurements of lift, drag, pitching moment, and dynamic pressure of the air in the slot were made for a complete range of angles of attack up to the stall for flap deflections of 0° and 40°.

RESULTS

The airfoil section coefficients are given in standard nondimensional coefficient form as follows:

c_l, section lift coefficient, l/qc_w.

c_{d_o}, section profile-drag coefficient, d_o/qc_w.

$c_{m_{(a.c.)_o}}$, section pitching-moment coefficient about aerodynamic center of airfoil with flap neutral, m_o/qc_w^2.

where l is section lift.

d_o, section profile drag.

m_o, section pitching moment (about aerodynamic center).

q, dynamic pressure, $\frac{1}{2} \rho V^2$.

c_w, airfoil chord including flap at $\delta_f = 0^\circ$.

and α_o is section angle of attack, deg.

δ_f, deflection of flap, deg.

V_o, average velocity obtained with the two impact tubes in the slot.

V, tunnel-air velocity.

ρ, air density.

Experimental errors in the results presented in this report are believed to be within the following limits:

c_l - - - - - ± 0.02 (near maximum lift)

c_{d_o} - - - - - ± 0.0003 (minimum drag with $\delta_f = 0^\circ$)

$c_{m_{(a.c.)_o}}$ - - - - - ± 0.0005

α_o - - - - - $\pm 0.1^\circ$

α_o at $c_{l_{max}}$ - - - 1.0° to 0° (i.e., α_o may be 1.0° higher than given).

V_o/V - - - - - ± 0.1

δ_f - - - - - $\pm 0.5^\circ$

No tests were made to determine the effect of flap or slat support fittings. The lift and the drag coefficients have been corrected for tunnel-wall effects, as explained in reference 3.

The section characteristics of the airfoil with the slotted flap deflected 0° and 40° with no slot and with several of the fixed slots are given as curves of c_{d_o}, $c_{m_{(a.c.)_o}}$, α_o, and V_o/V plotted against c_l in figures 6 to 11. These curves are given to show the general variations in the aerodynamic characteristics produced by the fixed slots. The characteristics of the basic wing with no flaps nor slots have been given in reference 3 and are included in figure 6 for comparison with the data of the wing with slotted flaps.

Figures 2, 4, and 5 included tables of important airfoil section characteristics for all slots tested. The characteristics given are: c_{d_o} at $c_l = 0.3$ and 1.0 with the flap deflected 0°, and at $c_l = 1.5$ and 2.0 with the flap deflected 40°; $c_{l_{max}}$; α_o at $c_{l_{max}}$; and $\dfrac{c_{l_{max}}}{c_{d_o}\ (\text{at } c_l = 0.3)}$ for both flap deflections.

DISCUSSION

Slots at the 0.55 c_w Location

The slots tested at 0.55 c_w were practically ineffective for increasing $c_{l_{max}}$ or α_o at $c_{l_{max}}$, especially with the flap deflected 40° (figs. 2, 6, and 7). The aerodynamic characteristics of these slots did not vary in the same manner with changes in slot parameters as did the slots near the leading edge of the airfoil; the following discussion will therefore be devoted to the slot positions near the leading edge of the airfoil.

Slots Near the Leading Edge of the Airfoil

<u>$c_{l_{max}}$</u>.- There appears to be little difference in the values of $c_{l_{max}}$ obtained with any of the three slat chords when all the slot parameters are taken into consideration. The maximum values of $c_{l_{max}}$, however, were obtained with a slat chord of 0.165 c_w (figs. 4 and 5). The values of $c_{l_{max}}$ increase as the gap increases but, for

gaps greater than about $0.04c_w$, the increases are small. Variations in other slot parameters, provided that the ratio of gap to width is less than about 0.6, appear to have little effect on $c_{l_{max}}$.

α_o at $c_{l_{max}}$.- The variation in α_o at $c_{l_{max}}$ with slot position is shown in figures 12 and 13. The maximum values of α_o were obtained with slat chords of $0.165c_w$ and $0.129c_w$. For the $0.129c_w$ slat, the values of α_o depended largely upon the gap; for $0.165c_w$ and wider slats, slat chord had the greatest effect although the higher angles were generally obtained with the larger gaps. Variations in the other slot parameters, provided that the gap-width ratio was less than about 0.6, appeared to have little effect on α_o at $c_{l_{max}}$.

c_{d_o} (at c_l = 0.3).- The values of c_{d_o} (at c_l = 0.3) are given in the tables of figures 4 and 5 because they are representative of the high-speed condition with fixed slots. (See figs. 8 and 10.)

For slots with a sharp lower edge on the slat, the gap $0.02c_w$ and larger, and the width $0.05c_w$ and larger (slots for which the polars were similar to those given in fig. 10), the values of c_{d_o} (at $c_l = 0.3$) are given by a simple expression to an accuracy nearly within that of the test results. The relation is

$$c_{d_o} \text{ (at } c_l = 0.3) = 0.0119 + 0.36 \times \text{gap} + 0.125\,(K - \text{width})$$

where 0.0119 is the c_{d_o} of the airfoil without slots.

0.36 and 0.125 are constants.

Gap and width are in fractions of the airfoil chord.

K is a constant for each slat.

The values of K are:

Slat chord (fraction c_w)	Cut-off (fraction c_w)	K
0.205	0.05	0.102
.165	.05	.108
.165	.03	.130
.129	.0091	.102

The equation shows that the value of c_{d_o} (at c_l = 0.3) increases directly with the gap and decreases directly as the width increases from a width of about $0.05c_w$. A change in cut-off ($0.05c_w$ to $0.03c_w$ with the $0.165c_w$ slat chord) shows a difference in K of 0.022, which is practically the same as the difference in cut-off, $0.02c_w$. This result indicates that the effect of cut-off on c_{d_o} (at $c_l = 0.3$) is small, provided that the slat chord and the rear part of the slot form are the same.

For the slots with small gaps or widths, the computed values of c_{d_o} (at $c_l = 0.3$) are always greater than the measured values. Other factors remaining equal, the values of c_{d_o} (at $c_l = 0.3$) increase with slot width up to a width of about $0.04c_w$ and, for larger widths, c_{d_o} decreases according to the preceding expression.

$\dfrac{c_{l_{max}}}{c_{d_o}\ (\text{at } c_l = 0.3)}$.- The ratio $c_{l_{max}}/c_{d_{o_{min}}}$ has been given as a speed-range criterion, which is convenient for the comparison of the over-all efficiency of airfoils. There appears to be no consistent variation of this ratio with slot parameters and it is always less than for the wing without slots. Figures 14 and 15 give the variations of $\dfrac{c_{l_{max}}}{c_{d_o}\ (\text{at } c_l = 0.3)}$ with the gap-width ratio for all the slots tested and indicate that the over-all efficiency of the airfoil improves as the gap becomes smaller or as the width becomes larger.

Effect of Rounding Lower Edge of Slot

For the slot at the $0.55c_w$ position, rounding the lower edge of the slat increased the value of c_{d_o} (at $c_l = 0.3$). (See fig. 2.) Rounding the lower edge of the $0.165c_w$ slat decreased c_{d_o} for values of c_l above 0.2. (See figs. 5 and 10.) For the few cases tried, the reduction in c_{d_o} is very similar to that obtained by increasing the slot width with the sharp-edge slats. Rounding the lower edge of the slat to radii of $0.03c_w$ and $0.04c_w$ increased both $c_{l_{max}}$ and α_o at $c_{l_{max}}$. Raising the leading edge of the nose increased the value of c_{d_o} (at $c_l = 0.3$) with practically no change in the other aerodynamic characteristics.

Air Flow Over the Upper Surface of the Airfoil

For all the slots tested with slat chords of $0.55c_w$ and $0.129c_w$, the air flow both ahead of and behind the slot changed from smooth to burbled flow at the same time. With the $0.165c_w$ and $0.205c_w$ slats, the tufts showed that the flow reversed over the rear part of the slat 2^o or 3^o before it did over the rest of the upper surface of the airfoil.

Usually $c_{l_{max}}$ was obtained just before the air flow over the entire wing changed from smooth to burbled flow. In some cases, however, $c_{l_{max}}$ was obtained 2^o or 3^o before the tufts indicated reversal of air flow over the wing and the flap. For these cases, there probably was a very thick slow-moving boundary layer or actual reversal of flow far enough above the wing surface so that the tufts were not affected.

These observations tend to bear out the indications of the force measurements, that higher maximum values of c_l and α_o at $c_{l_{max}}$ would be obtained with a slat which would not stall before the rest of the wing. This conclusion indicates that a slat chord less than $0.165c_w$ and greater than $0.129c_w$ would be the most effective.

General Remarks

From the results obtained, it appears that a slat chord of about $0.15c_w$ and a gap of less than $0.04c_w$ would give the most practical arrangement for $c_{l_{max}}$ and for maximum angles of attack at $c_{l_{max}}$. With this slot, a width of about $0.07c_w$ or larger and a radius of about $0.04c_w$ for the lower edge of the slat would give the lowest values of c_{d_o} (at $c_l = 0.3$).

It is believed that the best slat-chord and slot-gap ranges for the N.A.C.A. 23012 airfoil have been covered in this investigation. Larger slot widths and better shaped lower-surface slot openings than were covered in this investigation would probably reduce the drag coefficient.

This type of slot is likely to be used principally for lateral stability at high angles of attack because of the low values of $\frac{c_{l_{max}}}{c_{d_o}\ (\text{at}\ c_l = 0.3)}$. For lateral stability, the slot would extend over only the outer portion of the wings and the gap would be large enough to give only the necessary increase in angle of attack required because, with the better slot shapes, the value of c_{d_o} (at $c_l = 0.3$) when $\delta_f = 0^\circ$ increases nearly as a straight-line variation with α_o at $c_{l_{max}}$ when $\delta_f = 40^\circ$.

If it is assumed that the maximum useful angle of attack is limited to 2° or 3° below that at which the tips stall and that a fixed slot is used over the outer part of the wing, an appreciable reduction in wing area might be realized for the same low speed and there might be a possible increase in the high speed of the airplane.

CONCLUSIONS

For the range of fixed-slot variables investigated, the following conclusions may be drawn for an N.A.C.A. 23012 airfoil with a slotted flap:

1. The slat chord and the slot gap and width are the only slot parameters that have appreciable effects on $c_{l_{max}}$ or on α_o at $c_{l_{max}}$.

2. A slat chord of about $0.15c_w$ would probably be the most effective for increasing $c_{l_{max}}$ and α_o at $c_{l_{max}}$.

3. A slot gap of $0.03c_w$ or $0.04c_w$ is about as large as is practicable for use with a fixed slot because, for larger gaps, the values of c_{d_o} show a much greater proportional increase than do the values of $c_{l_{max}}$ or α_o at $c_{l_{max}}$.

4. The gap-width ratio, provided that it is less than 0.6, has little effect on $c_{l_{max}}$ or α_o at $c_{l_{max}}$ with the flap deflected 40°.

5. The value of c_{d_o} with $\delta_f = 0^\circ$ increases with the gap and the width up to a width of about $0.04c_w$. For widths of about $0.05c_w$ and greater, the c_{d_o} decreases as the width increases. Other factors being equal, decreasing the cut-off increased c_{d_o} with $\delta_f = 0^\circ$.

6. Rounding the lower edge of the slat ($0.165c_w$ slat, $0.05c_w$ cut-off) reduced the c_{d_o} throughout the normal flying range, and a radius of $0.03c_w$ and larger increased both $c_{l_{max}}$ and α_o at $c_{l_{max}}$.

7. The value of the ratio $\dfrac{c_{l_{max}}}{c_{d_o}\ (\text{at } c_l = 0.3)}$ was

always less than that for the wing with no slot and it decreased as the gap-width ratio increased.

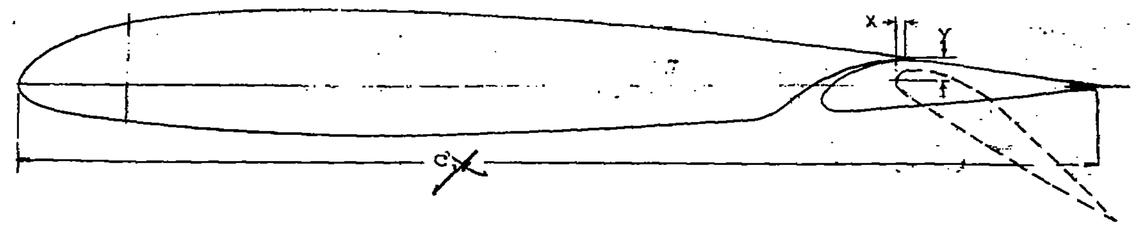
Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., November 21, 1938.

REFERENCES

1. Weick, Fred E., and Wenzinger, Carl J.: The Characteristics of a Clark Y Wing Model Equipped with Several Forms of Low-Drag Fixed Slots. T.R. No. 407, N.A.C.A., 1932.

2. Weick, Fred E., and Shortal, Joseph A.: The Effect of Multiple Fixed Slots and a Trailing-Edge Flap on the Lift and Drag of a Clark Y Airfoil. T.R. No. 427, N.A.C.A., 1932.

3. Wenzinger, Carl J., and Harris, Thomas A.: Wind-Tunnel Investigation of an N.A.C.A. 23012 Airfoil with Various Arrangements of Slotted Flaps. T.R. No. 664, N.A.C.A., 1939.



ALL DIMENSIONS IN PERCENT OF WING CHORD

NACA 23012 AIRFOIL		
STATION	UPPER SURFACE	LOWER SURFACE
0	–	0
1.25	2.67	-1.23
2.5	3.61	-1.71
5.0	4.91	-2.26
7.5	5.80	-2.61
10	6.43	-2.92
15	7.19	-3.50
20	7.50	-3.97
25	7.60	-4.28
30	7.55	-4.46
40	7.14	-4.48
50	6.41	-4.17
60	5.47	-3.67
70	4.36	-3.00
80	3.08	-2.16
90	1.68	-1.23
95	.92	-.70
100	.13	-.13

LEADING-EDGE RADIUS: 1.58
SLOPE OF RADIUS THROUGH END OF CHORD: 0.305

PATH OF FLAP NOSE		
δ_f (deg.)	~~x~~ y	~~y~~ x
0	8.36	3.91
10	5.41	3.63
20	3.83	3.45
30	2.63	3.37
40	1.35	2.43
50	.50	1.63
60	.12	1.48

SLOTTED FLAP		
STATION	UPPER SURFACE	LOWER SURFACE
0	-1.29	-1.29
.40	-.32	-2.05
.72	.04	-2.21
1.36	.61	-2.36
2.00	1.04	-2.41
2.64	1.40	-2.41
3.92	1.94	———
5.20	2.30	———
5.66	———	-2.16
6.48	2.53	———
7.76	2.63	———
9.03	2.58	———
10.31	2.46	———
15.66	1.68	-1.23
20.66	.92	-.70
25.66	.13	-.13

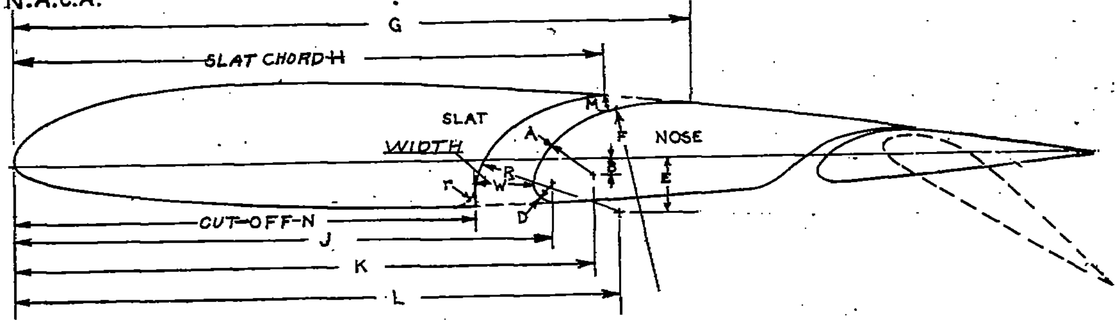
CENTER OF LEADING-EDGE ARC: 0.91 | -1.29
LEADING-EDGE RADIUS: 0.91

CONTOUR OF SLOT	
STATION	ORDINATE
72.32	-1.02
74.57	.67
76.32	1.76
77.82	2.30
79.32	2.65
80.82	2.82
82.70	2.64

ARC CENTER		ARC RADIUS
66.65	4.67	7.97

Figure 1.– Cross-sectional view of the N.A.C.A 23012 airfoil with slotted flap.

N.A.C.A. Fig. 2



SLOT DIMENSIONS

NOSE	A	B	K		D	J	F	G	M
1	5.52	2.0	55.52		2.0	52.0	20.0	65.0	2.0
2	4.45	.59	56.0		2.0	54.0	20.0	65.0	2.0
3	5.70	.80	55.5		2.0	52.0	20.0	65.0	1.0
4	4.60	.30 ABOVE CHORD	55.22		2.0	54.0	20.0	65.0	1.0
5	8.53	4.3	60.02		2.0	54.0	17.05	65.0	3.0

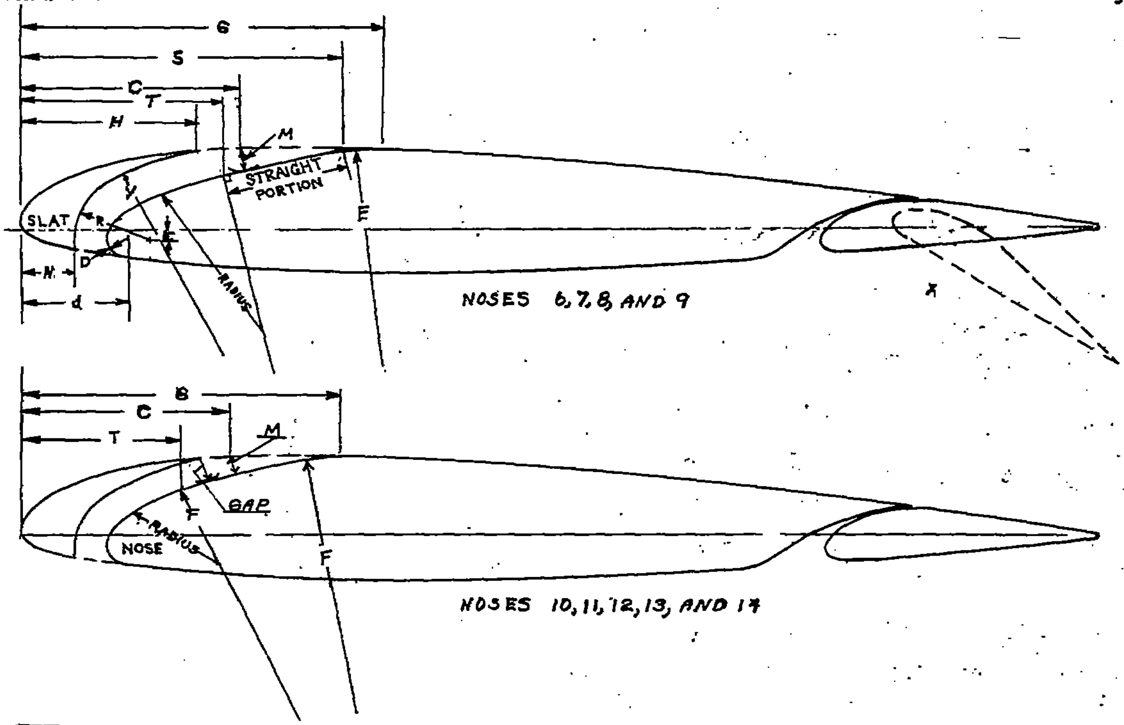
SLAT	R	L	E	H	N
1	10.0	55.0	4.0	55.0	45.0
2	11.0	54.0	4.92	55.0	43.0

ALL DIMENSIONS IN PERCENT OF WING CHORD

SLOT CHARACTERISTICS

								FLAP ANGLE = 0°					FLAP ANGLE = 40°				
NOSE	SLAT	CUTOFF N	SLAT CHORD H	WIDTH W	GAP M	GAP÷WIDTH RATIO	EDGE RADIUS r	c_{d_0} AT $c_l=0.3$	c_{d_0} AT $c_l=1.0$	$c_{l_{max}}$	α AT $c_{l_{max}}$ (deg.)	$c_{l_{max}}/c_{d_0}$ (at $c_l=0.3$)	c_{d_0} AT $c_l=1.5$	c_{d_0} AT $c_l=2.0$	$c_{l_{max}}$	α AT $c_{l_{max}}$ (deg.)	$c_{l_{max}}/c_{d_0}$ (at $c_l=0.3$)
NO MIDCHORD SLOT								0.0119	0.0202	1.51	14.7	127	0.0610	0.0760	2.68	10.9	225
3	1	45.	.55	5	1	0.20	0	.0150	.0293	1.62	18.2	108.	.0681	.0822	2.71	12.9	181
3	1	45	55	5	1	.20	1.0	.0160	.0295	1.58	17.2	99.	.0660	.0853	2.71	12.9	169
4	1	45.	.55	7	1	.143	0	.0153	.0293	1.62	18.2	106.	.0675	.0820	2.70	12.9	176
4	2	.43	.55	9	1	.111	0	.0160	.0300	1.62	18.2	101.	.0679	.0841	2.70	12.9	169
2	1	45.	.55	9	2	.286	0	.0179	.0328	1.60	17.2	89.	.0707	.0885	2.71	13.9	151
2	2	43.	.55	9	2	.222	0	.0185	.0320	1.63	17.2	88.	.0710	.0855	2.69	12.9	145
5	2	43	.55	9	3	.333	0	.0240	.0340	1.62	17.2	68	.0741	.0898	2.70	13.9	112

Figure 2.- Cross-sectional view and aerodynamic characteristics of an N.A.C.A. 23012 airfoil with fixed slot. Slat Chord, $0.55c_w$.



NOSE	J	D	C	M	S	F	G	T
6	12	2	20.5	.305	32	33	36	18
7	14	2	20.5	.305	32	33	36	19
8	16	2	20.5	.305	32	33	36	20
9	10	2	20.5	.205	30	36	34.7	19
10	12	2	20.5	2.05	—	42	33	13
11	14	2	20.5	2.05	—	42	33	18
12	10	2	20.5	1.05	—	40	29	13
13	12	2	20.5	1.05	—	40	29	16
14	5.9	2	13	1.05	—	29	22	8

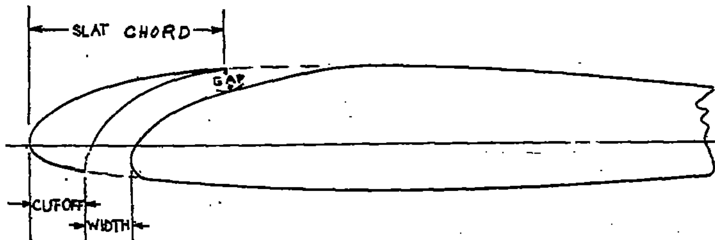
SLAT	H	R	E	Y	N
4	12.9	6.85	2.29	(a)	0.91
5	16.5	6.75	1.28	21	5
6	20.5	7.0	2.22	30	5
7	16.5	5.1	1.80	21	3

[a] FOR SLAT 4 USE THE FOLLOWING POINTS IN PLACE OF RADIUS Y

STATION	5.0	7.5	10.0	12.5
ORDINATE	4.11	5.22	6.07	6.80

ALL DIMENSIONS GIVEN IN PERCENT OF WING CHORD

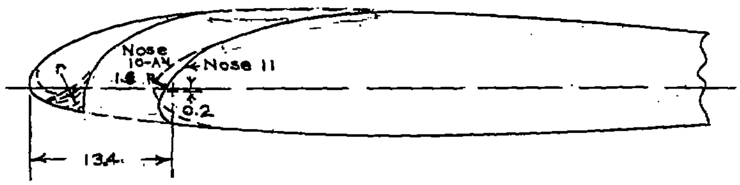
Figure 3.— Cross-sectional view of the N.A.C.A. 23012 airfoil with fixed slots. Slat chords, $0.129c_w$, $0.165c_w$, and $0.205c_w$.



All dimensions in percent of wing chord

NOSE	SLAT	CUTOFF	SLAT CHORD	WIDTH	GAP	GAP-WIDTH RATIO	Flap angle = 0°: c_{d_0} at $c_l = 0.3$	Flap angle = 0°: c_{d_0} at $c_l = 1.0$	Flap angle = 0°: $c_{l_{max}}$	Flap angle = 0°: α at $c_{l_{max}}$ (deg.)	Flap angle = 0°: $c_{l_{max}}/c_{d_0}$ (at $c_l = 0.3$)	Flap angle = 40°: c_{d_0} at $c_l = 1.5$	Flap angle = 40°: c_{d_0} at $c_l = 2.0$	Flap angle = 40°: $c_{l_{max}}$	Flap angle = 40°: α at $c_{l_{max}}$ (deg.)	Flap angle = 40°: $c_{l_{max}}/c_{d_0}$ (at $c_l = 0.3$)
NO NOSE SLOT							.0119	.0202	1.51	14.7	127	.0610	.0760	2.68	10.9	225
12	6	5.0	20.5	3.0	1.00	0.333	.0185	.0290	1.77	21.2	96.	.0692	.0860	2.68	13.9	145
13	6	5.0	20.5	5.0	1.00	.200	.0172	.0260	1.79	22.2	104.	.0692	.0880	2.68	13.9	156
9	6	5.0	20.5	3.0	2.00	.667	.0249	.0417	1.89	21.2	76.	.0792	.0970	2.89	15.9	116
10	6	5.0	20.5	5.0	2.00	.400	.0249	.0295	1.95	21.2	78.	.0745	.0875	2.89	14.9	116
11	6	5.0	20.5	7.0	2.00	.286	.0220	.0269	1.96	22.2	89.	.0713	.0865	2.89	15.9	131
6	6	5.0	20.5	5.0	3.00	.600	.0285	.0382	2.00	22.2	70.	.0780	.0930	2.93	15.9	103
7	6	5.0	20.5	7.0	3.00	.429	.0264	.0294	2.00	22.2	76.	.0715	.0868	2.90	15.9	110
8	6	5.0	20.5	9.0	3.00	.333	.0240	.0263	2.02	22.2	84.	.0710	.0860	2.86	15.9	119
9	5	5.0	16.5	3.0	2.88	.960	.0291	.0620	1.64	24.2	56.	.0772	.1040	2.36	18.9	81.
10	5	5.0	16.5	5.0	3.18	.636	.0327	.0405	2.06	24.2	63.	.0769	.0922	2.95	16.9	90
11	5	5.0	16.5	7.0	3.17	.453	.0277	.0310	2.09	24.2	76.	.0749	.0888	2.95	17.9	106
8	5	5.0	16.5	9.0	4.14	.460	.0285	.0322	2.16	25.2	74.	.0755	.0918	2.93	18.9	103
13	7	3.0	16.5	7.0	1.88	.269	.0230	.0255	2.04	23.2	89.	.0702	.0865	2.87	16.9	125
9	7	3.0	16.5	5.0	2.88	.576	.0320	.0372	2.11	24.2	66.	.0798	.0940	2.98	17.9	93
6	7	3.0	16.5	7.0	3.92	.560	.0335	.0332	2.13	25.2	67.	.0792	.0900	3.01	18.9	90
7	7	3.0	16.5	9.0	3.94	.438	.0302	.0302	2.13	24.2	71.	.0777	.0899	3.01	18.9	100
8	7	3.0	16.5	11.0	4.14	.376	.0290	.0285	2.15	25.2	74.	.0756	.0880	2.98	19.9	103
10	7	3.0	16.5	7.0	3.18	.454	.0305	.0307	2.14	25.2	70.	.0751	.0900	2.98	18.9	99
14	4	.91	12.9	3.0	1.00	.333	.0193	.0230	1.83	21.2	95.	.0686	.0810	2.74	12.9	142.
12	4	.91	12.9	7.09	2.89	.408	.0260	.0250	2.00	23.2	77.	.0720	.0830	2.79	14.9	107
13	4	.91	12.9	9.09	2.97	.327	.0240	.0232	1.99	22.2	83.	.0700	.0811	2.78	13.9	116
11	4	.91	12.9	11.09	4.61	.416	.0290	.0260	2.07	25.2	72	.0728	.0836	2.86	16.9	99.
7	4	.91	12.9	11.09	5.17	.466	.0310	.0272	2.00	22.2	65.	.0752	.0880	2.93	18.9	95
8	4	.91	12.9	13.09	6.01	.460	.0305	.0268	2.07	24.2	68.	.0742	.0858	2.93	18.9	96

Figure 4.— Aerodynamic characteristics of the N.A.C.A. 23012 airfoil with fixed slots. Slat chords, $0.129c_w$, $0.165c_w$, and $0.205c_w$.



Slat	5	5A	5B	5C	5D	5E	5F
r	0	1	2	3	[a]4	[a]10	[b]18

a Tangent to leading-edge radius.
b Tangent to upper and lower surface of slat 5 E. Center at 25.

All dimensions in percent of wing chord

				Flap angle = 0°					Flap angle = 40°				
Nose	Slat	Width	Gap	c_{d_0} at $c_l = 0.3$	c_{d_0} at $c_l = 1.0$	$c_{l_{max}}$	α at $c_{l_{max}}$ (deg.)	$\frac{c_{l_{max}}}{c_{d_0}}$ (at $c_l = 0.3$)	c_{d_0} at $c_l = 1.5$	c_{d_0} at $c_l = 2.0$	$c_{l_{max}}$	α at $c_{l_{max}}$ (deg.)	$\frac{c_{l_{max}}}{c_{d_0}}$ (at $c_l = 0.3$)
No nose slot				0.0119	0.0202	1.51	14.7	127	0.0610	0.0760	2.68	10.9	225
8	5	9.0	4.14	.0285	.0322	2.11	25.2	74	.0755	.0918	2.93	18.9	103
8	5A	—	4.14	.0283	.0293	2.13	25.2	75.	.0764	.0918	2.98	18.9	105
8	5B	—	4.14	.0277	.0279	2.12	25.2	77.	.0764	.0896	2.96	18.9	107
11	5	7.0	3.17	.0277	.0310	2.09	24.2	76.	.0749	.0888	2.95	17.9	106
11	5B	—	3.17	.0255	.0268	2.08	24.2	82.	.0710	.0873	2.93	18.9	115
11	5C	—	3.17	.0242	.0242	2.16	25.2	89.	.0685	.0819	3.07	20.9	127
11	5D	—	3.17	.0239	.0224	2.11	23.2	88.	.0689	.0818	3.02	19.9	126
11	5E	—	3.17	.0245	.0197	2.16	24.2	88.	.0696	.0805	3.03	19.9	124
11	5F	—	3.17	.0224	.0204	2.02	22.2	90.	.0681	.0795	2.86	17.9	128
10A	5E	—	3.18	.0256	.0198	2.14	24.2	84	.0710	.0826	3.04	19.9	119

fig 10

Figure 5.— Cross-sectional view and aerodynamic characteristics of the N.A.C.A. 23012 airfoil with fixed slot. Slat chord, $0.165c_w$; rounded lower edge.

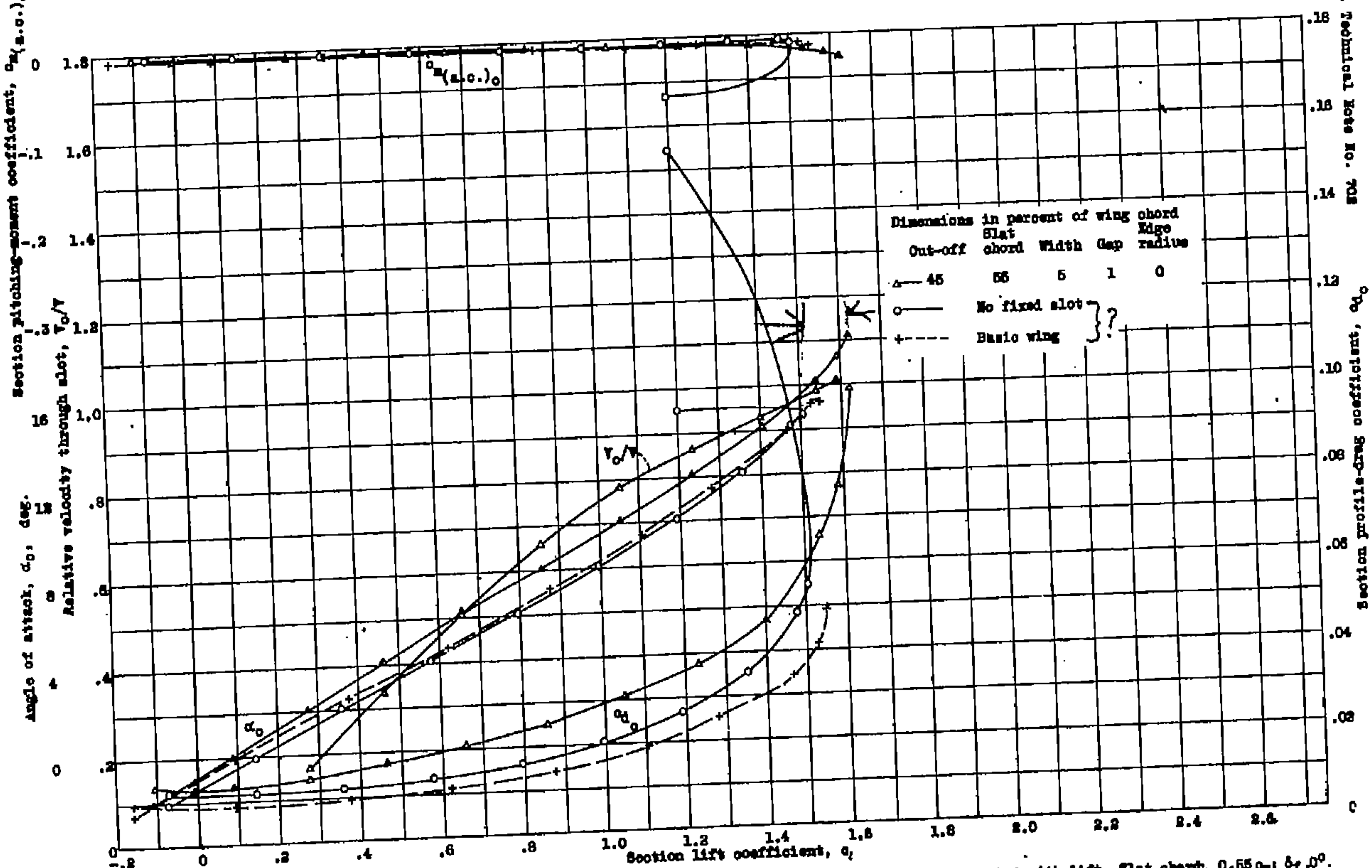


Figure 6.- Variation of section profile drag, angle of attack, pitching moment, and relative velocity through the slot with lift. Slat chord, 0.55 c_w; δ_f, 0°.

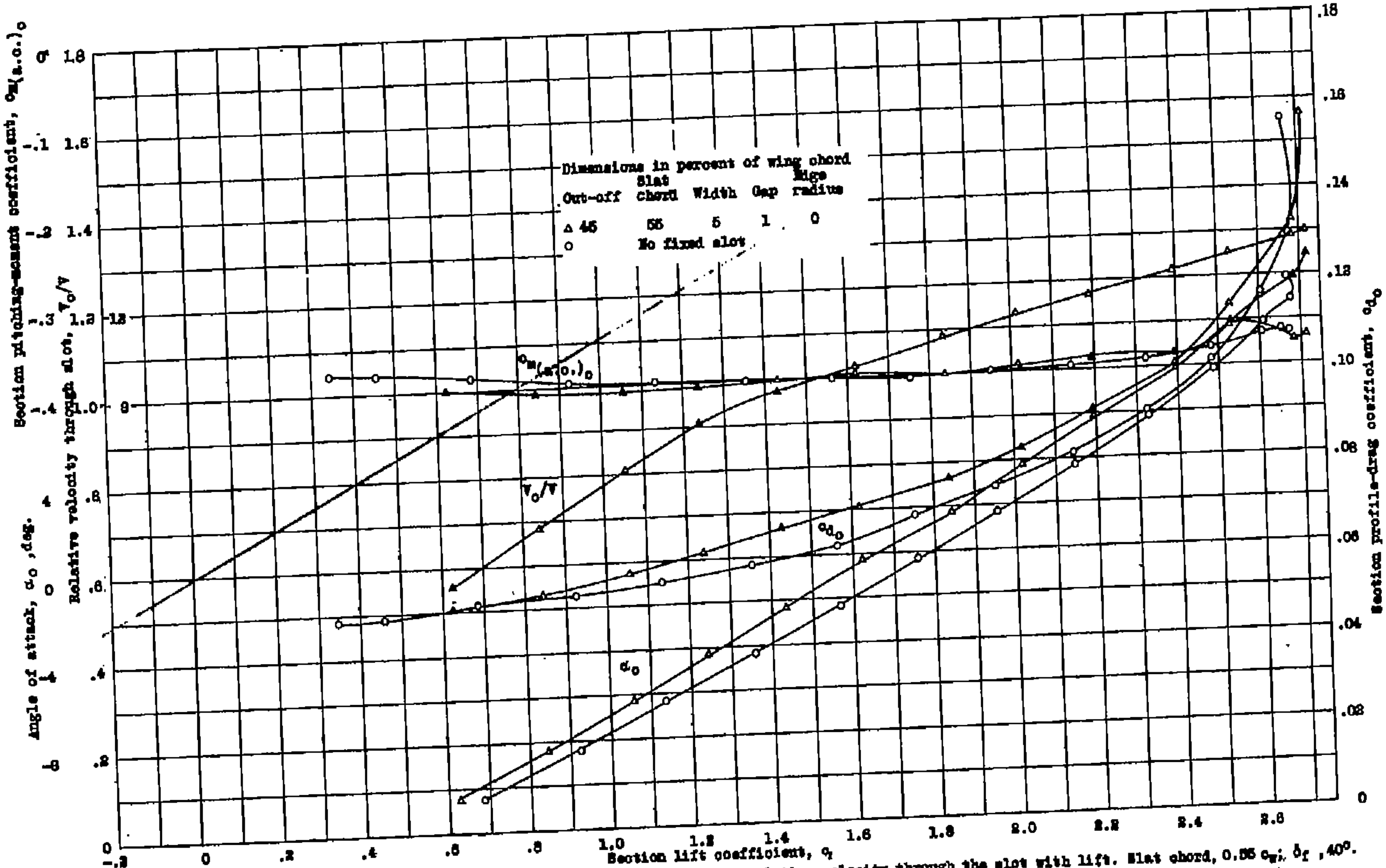


Figure 7.- Variation of section profile drag, angle of attack, pitching moment, and relative velocity through the slot with lift. Slat chord, 0.55 c_w; δ_f, 40°.

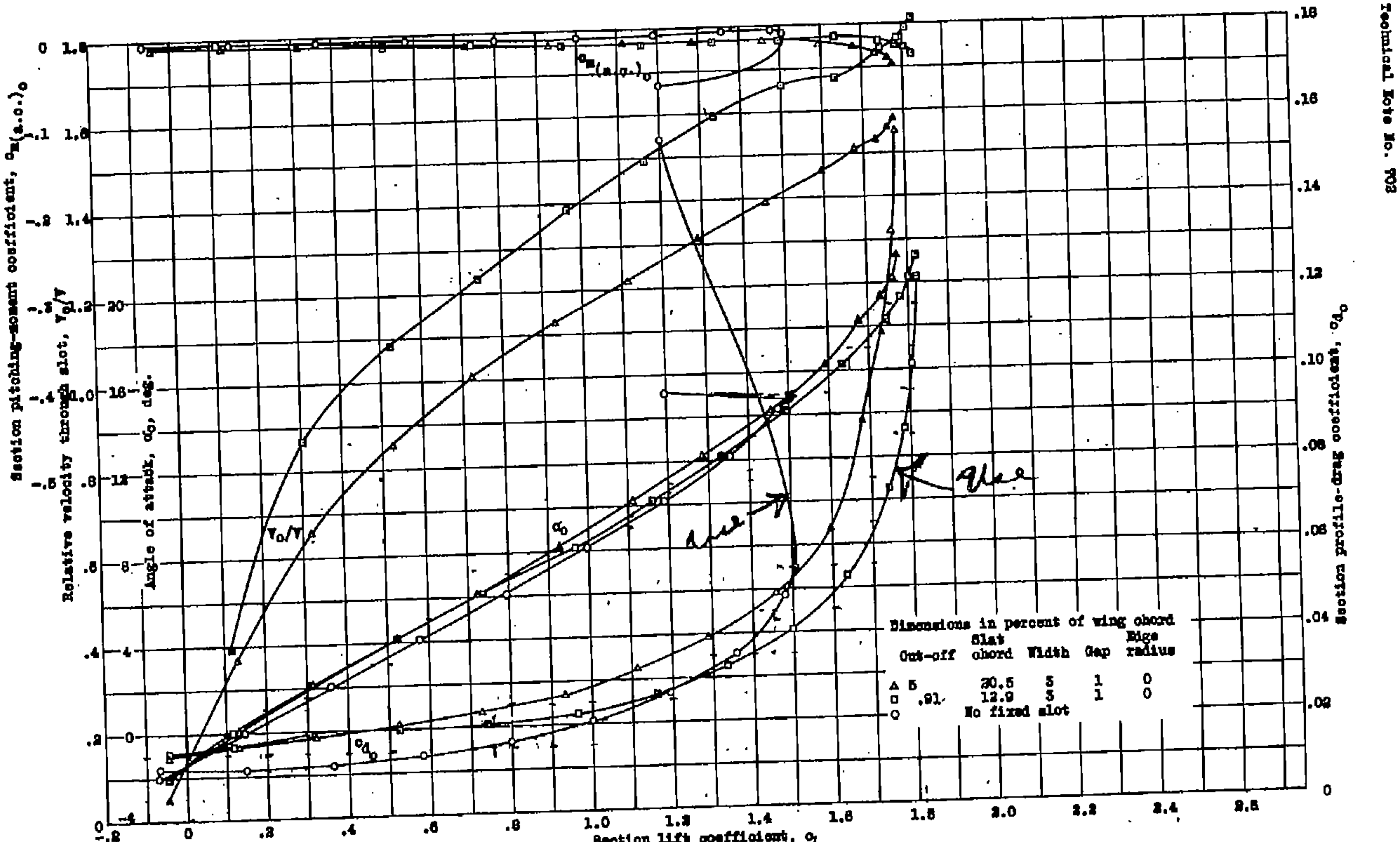


Figure 8.- Variation of section profile drag, angle of attack, pitching moment, and relative velocity through the slot with lift. Slat chords, 0.129 c_w and 0.205 c_w; δ_f, 0°.

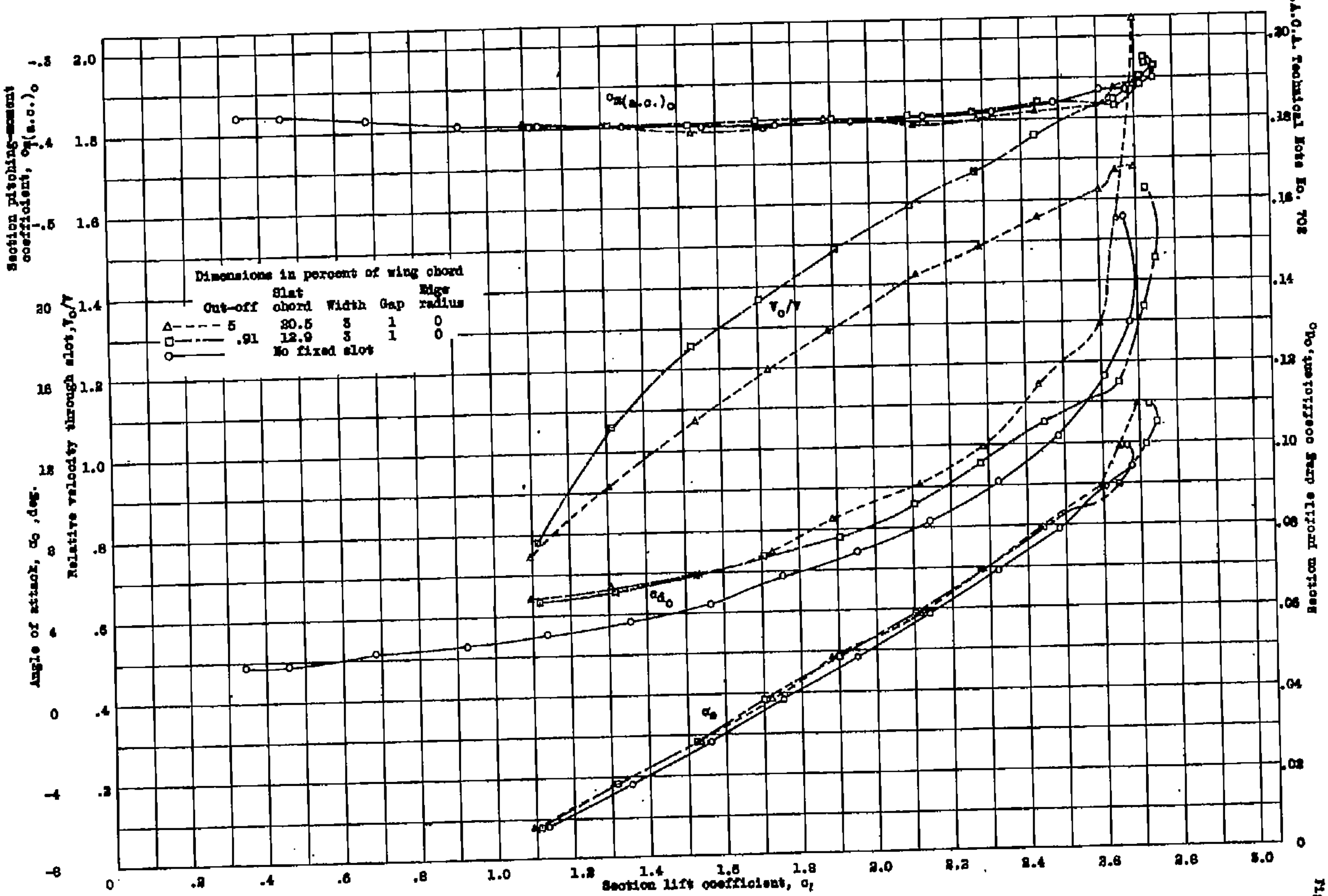


Figure 9.- Variation of section profile drag, angle of attack, pitching moment, and relative velocity through the slot with lift. Slat chords 0.129c_w and 0.205c_w ; δ_f ,40°.

Fig. 9

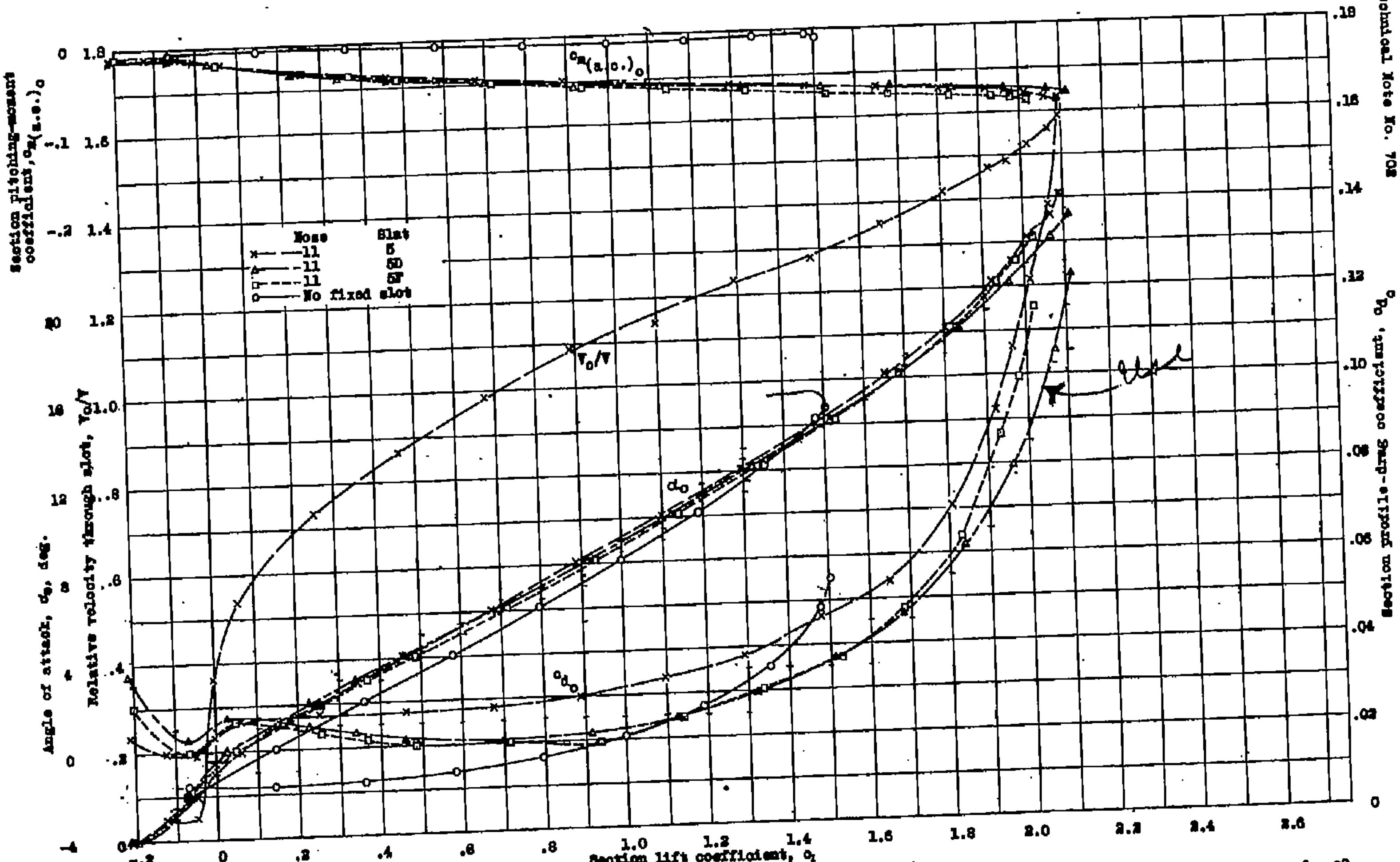


Figure 10.- Variation of section profile drag, angle of attack, pitching moment, and relative velocity through the slot with lift. Slat chord, 0.165 c_w; δ_f, 0°.

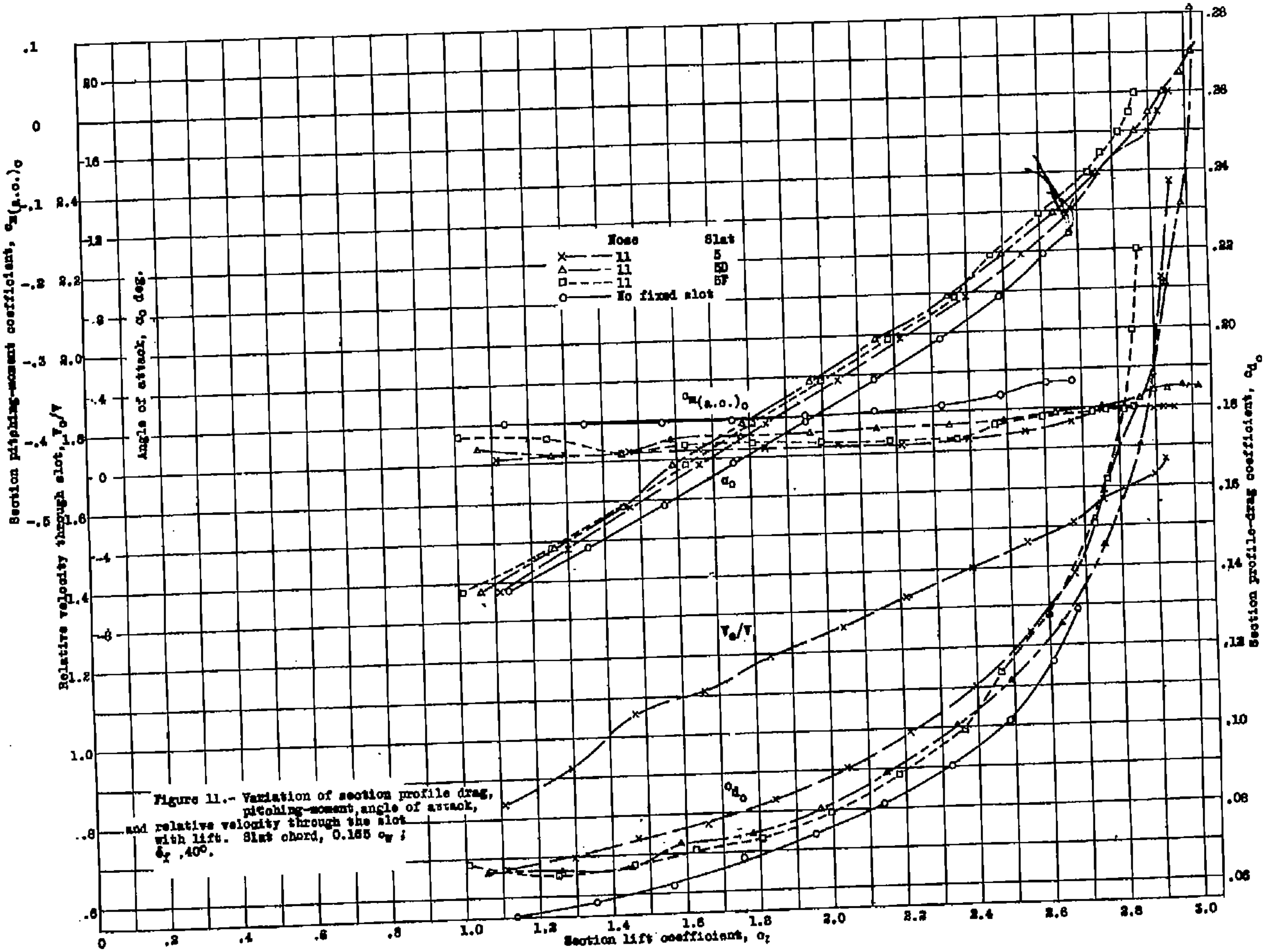


Figure 11.- Variation of section profile drag, pitching-moment, angle of attack, and relative velocity through the slot with lift. Slat chord, 0.155 c_w; δ_f, 40°.

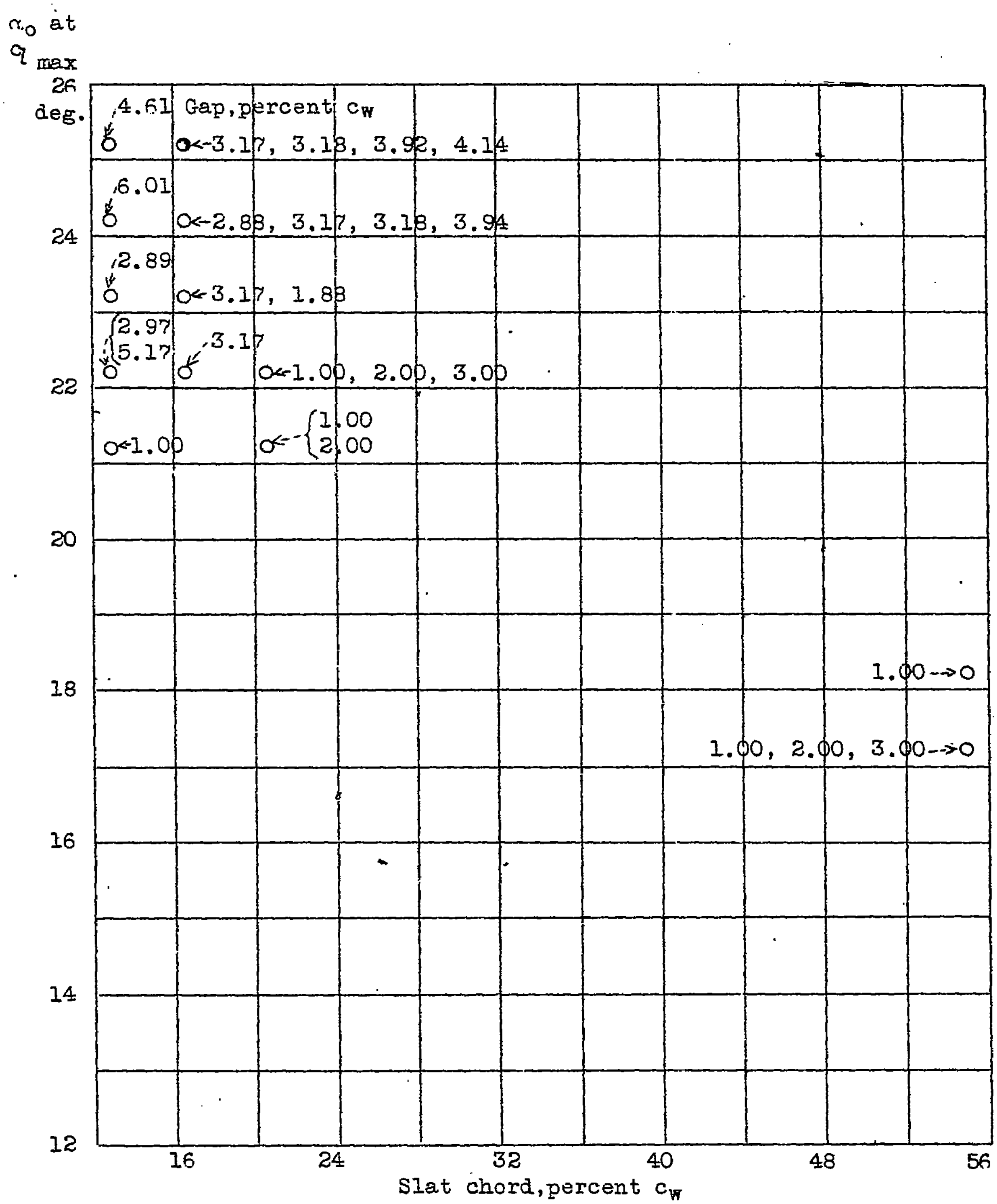


Figure 12.- Variation of angle of attack at maximum lift with slat chord. δ_f, 0°.

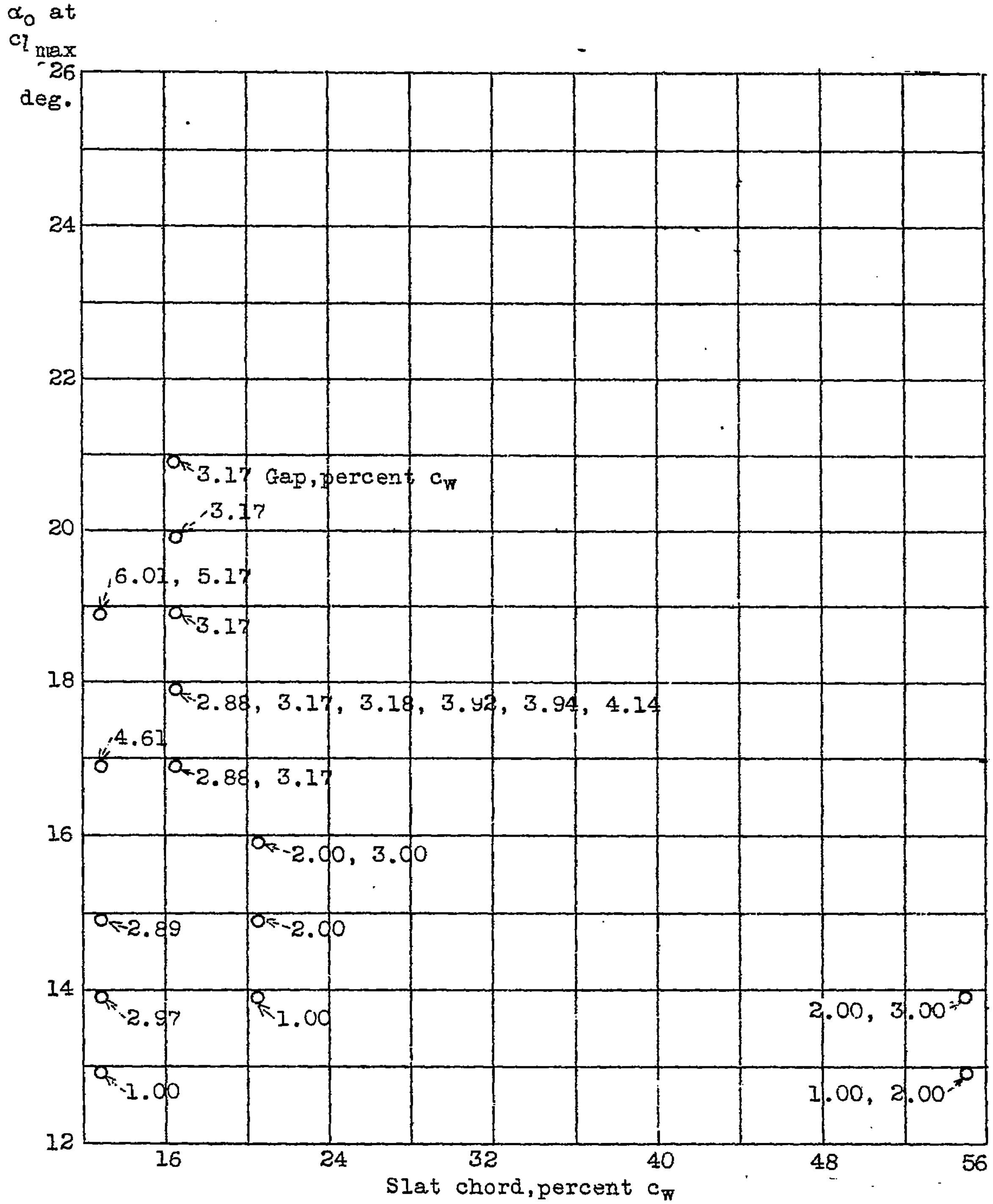


Figure 13.- Variation of angle of attack at maximum lift with slat chord, δ_f, 40°.

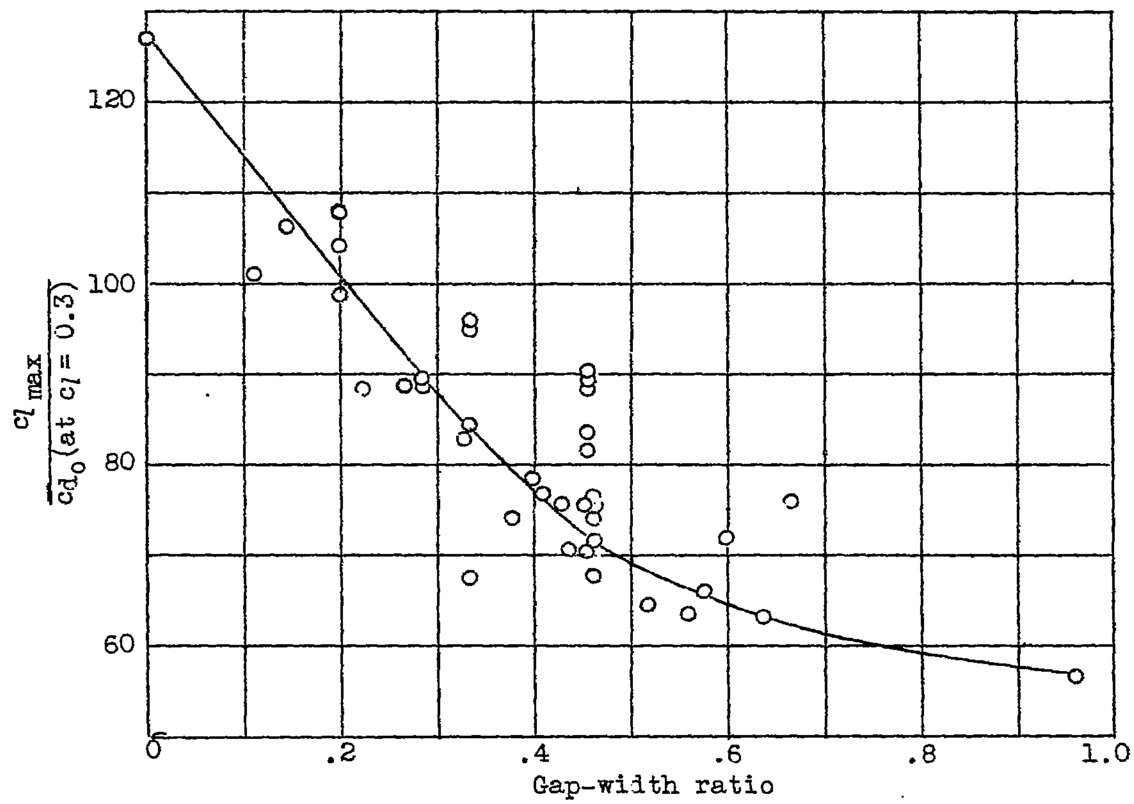


Figure 14.- Variation of $\frac{c_{l_{max}}}{c_{d_o} \text{ (at } c_l = 0.3)}$ with gap-width ratio. δ_f, 0°.

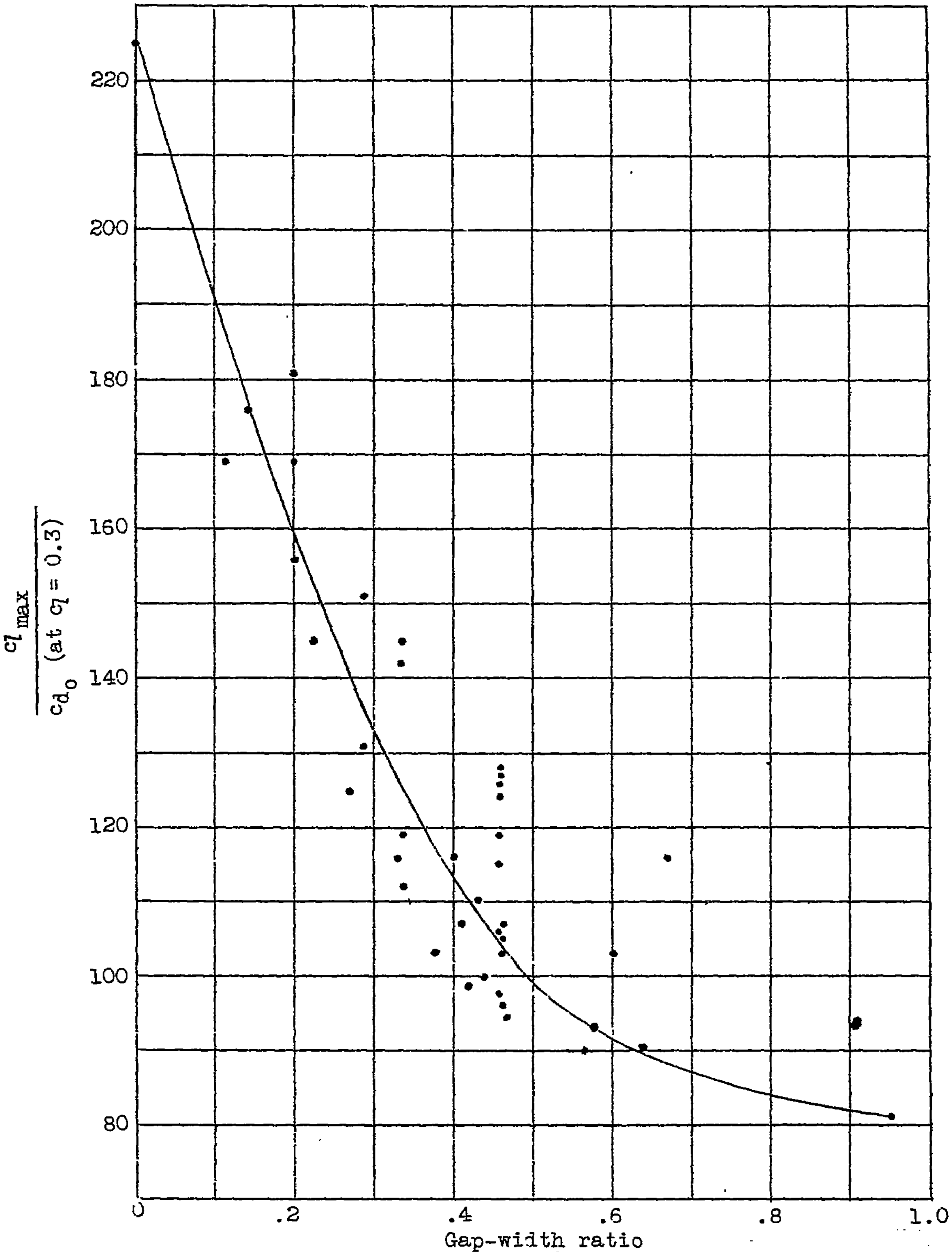


Figure 15.- Variation of $\dfrac{c_{l_{max}}}{c_{d_o}\ (\text{at } c_l = 0.3)}$ with gap-width ratio, δ_f, 40°.